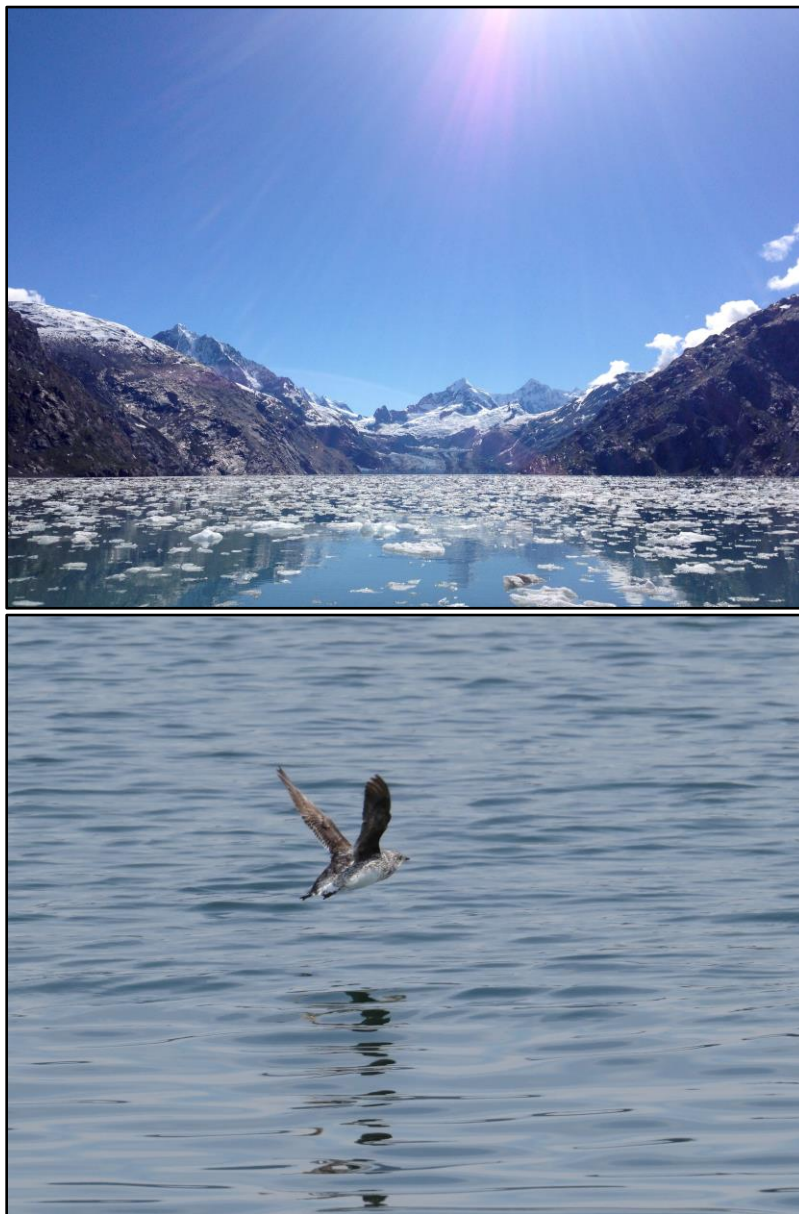




Monitoring Kittlitz's and Marbled Murrelets in Glacier Bay National Park and Preserve

2014 Annual Report

Natural Resource Technical Report NPS/SEAN/NRTR—2014/925



ON THE COVER

Photo descriptions: Johns Hopkins Inlet (top), Kittlitz's murrelet in flight (bottom)

Photographs by: Kelly Nesvacil, Alaska Department of Fish and Game

Monitoring Kittlitz's and Marbled Murrelets in Glacier Bay National Park and Preserve

2014 Annual Report

Natural Resource Technical Report NPS/SEAN/NRTR—2014/925

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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Executive Summary

Since 2009, the National Park Service's Southeast Alaska Inventory and Monitoring Network (SEAN) has monitored population abundance and spatial distribution of Kittlitz's (KIMU) and marbled murrelets (MAMU) in Glacier Bay National Park and Preserve, an important summer residence for both species. Monitoring program design focuses on KIMU, with secondary consideration of MAMU. The SEAN uses boat-based line transect surveys to estimate species-specific, on-water density and abundance of murrelets, accounting for detection probability and unidentified murrelets.

We surveyed 246.5 km on 45 transects from 7-16 July 2014 across the 1,170 km² survey area in Glacier Bay proper. We estimated an abundance of 10,422 KIMU (SE = 1,522) and 41,474 MAMU (SE = 3,988). From 2009 to 2014, KIMU abundance estimates have ranged from 7,210 to 16,469 (6-year average = 11,335) with annual changes of -56% to 120%, while MAMU have ranged from 28,978 to 84,428 (6-year average = 57,154) with annual changes of -51% to 113%. Such large variation was very unlikely to reflect solely intrinsic population dynamics.

This season, in cooperation with S. Hoekman (Wild Ginger Consulting), the SEAN participated in field trials assessing multi-observer methods to reliably estimate species identification error rates during surveys. The results of this work will be reported in a future peer-reviewed publication.

During July 2013, SEAN staff and volunteers participated in a field experiment designed to evaluate the magnitude of KIMU versus MAMU identification error among six observers of differing experience levels and under a suite of environmental conditions. The results were applied to measure potential bias in abundance estimates induced from varying identification error rates. The average misidentification rate was low, with an average probability of 0.036 (SE = 0.004) across all observers. Observer experience was the main driver of variation in identification error rates, with more experienced observers making fewer errors. Therefore, these results emphasize the importance of conducting consistent, rigorous observer training before and during abundance surveys to increase confidence in species identification and precision in abundance estimates of both KIMU and MAMU.

After the 2015 survey, the SEAN will synthesize existing abundance and trend information and re-examine analytic methods to assess if monitoring in its current form is likely to achieve program objectives. Our results to-date demonstrate that key operational components of our monitoring protocol are functioning as intended.

The SEAN Kittlitz's Murrelets Resource Brief is a non-technical summary of recent monitoring program highlights and relevance to park management. It can be viewed and downloaded at:
http://science.nature.nps.gov/im/units/sean/auxrep/KM/KM_resource_brief.pdf

Acknowledgments

Since 2011, R. Sarwas has provided critical technical support for the NPTransect application. K. Nesvacil assisted with field surveys for the second year in a row and participated in murrelet species identification trials that will improve survey methods and results. The Glacier Bay National Park and Preserve Visitor Information Station oversaw boating logistics and safety while conducting surveys. Glacier Bay staff, especially L. Sharman, L. Etherington, and A. Banks, facilitated our research in the park. L. Sharman also contributed excellent ideas for the new monitoring program resource brief.

Introduction

Since 2009, the National Park Service's Southeast Alaska Inventory and Monitoring Network (SEAN) has monitored population abundance of Kittlitz's murrelets (*Brachyramphus brevirostris*, hereafter "KIMU") and marbled murrelets (*B. marmoratus*, hereafter "MAMU") in Glacier Bay National Park and Preserve. The program arose from concern over the conservation status of KIMU, potential global and local population declines (Piatt et al. 2011, USFWS 2013, Kirchhoff et al. 2014), and the hypothesis that KIMU populations respond to fluctuations in components of the Glacier Bay marine and terrestrial ecosystems (Moynahan et al. 2008). As part of its Vital Signs Monitoring Program, the SEAN designated KIMU as a priority natural resource with the specific objectives of monitoring abundance status and trend, and spatial distributions of populations.

The KIMU is a seabird endemic to Alaska and northeastern Russia, with the highest breeding population densities in the northern Gulf of Alaska (Day et al. 1999). KIMU in summer are often associated with tidewater glacier and glacial fjord habitats, but also occur in non-glacially influenced areas (Day et al. 1999, Arimitsu et al. 2011, Kissling et al. 2011, Madison et al. 2011). KIMU often forage in proximity to glacier outflows (Day and Nigro 2000, Kuletz et al. 2003) and nest in recently de-glaciated areas with sparse vegetation (Day 1995). As a summer resident, open-water, pursuit forager, KIMU are likely to play an important role as integrators of variation in marine and terrestrial ecosystems and directly relate to the conceptual ecological models in the SEAN Vital Signs Monitoring Plan (Moynahan et al. 2008). Although the specific ecosystem linkages are unclear (USFWS 2013), KIMU use of glacially-influenced habitats link this species to dynamic physical habitat conditions such as glacial extent and oceanography that are subject to chronic climate-induced changes (Larsen et al. 2007).

SEAN monitoring focuses on estimating early July population abundance and trend primarily for KIMU and secondarily for MAMU. Several challenges inherent to Glacier Bay and its murrelet populations complicate estimating murrelet abundance: difficulty distinguishing between the two cryptic species, incomplete detection of murrelets along transects, large spatial and temporal variation in populations, and convoluted topography that complicates survey transect placement. The 2009 and 2010 annual KIMU reports, in conjunction with the final long-term monitoring protocol (Hoekman et al. 2013a) fully describe monitoring methods developed to address these challenges.

These annual reports are designed to efficiently deliver data in a concise format, focusing on population abundance and spatial distributions. Periodic syntheses at six-year intervals will assess program performance and population trends. Our 2014 study objectives were to complete the sixth year of boat-based line transect surveys, estimate population abundance of KIMU and MAMU in Glacier Bay, describe their spatial distribution, and summarize results since 2009. This season, in cooperation with S. Hoekman (Wild Ginger Consulting), the SEAN participated in field trials assessing the use of multi-observer methods for reliably estimating murrelet species identification error rates by observers during surveys. During July 2013, in cooperation with the University of Montana and USFWS, the SEAN also participated in field trials assessing the magnitude of murrelet identification error among observers of differing experience levels. Together, these studies will enhance the training and performance of survey observers, improve survey methods, and increase the reliability of monitoring results by allowing for estimation of abundance correcting for identification error.

Methods

This section includes a brief overview of survey design, survey methods, and analytic approach. Full details can be found in the SEAN long-term monitoring protocol (Hoekman et al. 2013a); relevant protocol sections are referenced below.

Study area

Glacier Bay is a narrow, glacial fjord located in Southeast Alaska. The study area encompassed 1,170 km² of waters north of Icy Strait and excluded some areas designated as non-motorized waters or those that did not allow safe survey vessel passage (Figure 1).

See Chapter 1 of the SEAN long-term monitoring protocol (Hoekman et al. 2013a) and Hoekman et al. (2011a) for more detail.

Survey design

We employed a generalized random tessellation stratified sampling design (GRTS; Stevens and Olsen 2004) to minimize deleterious effects of large spatial variation in murrelet abundance (Drew et al. 2008, Hoekman et al. 2011a,b) by providing a random, spatially-balanced sample. We allocated survey effort relative to expected densities of KIMU using unequal probability sampling (Stevens and Olsen 2004). To avoid placing transects parallel to the observed density gradient of murrelets (Drew et al. 2008, Kirchhoff 2011) and to provide representative coverage across water depths, we oriented linear transects perpendicular to the local prevailing shoreline. In more enclosed waters we used shore-to-shore zigzag transects to avoid undesirably short transects. Transects are sampled according to an augmented, serially alternating panel design (McDonald 2003), where one panel (set of transects) is sampled annually and three others are visited on a three-year rotation, with 2014 including the second panel.

See Chapter 2 and Appendix B of the long-term monitoring protocol for more detail (Hoekman et al. 2013a).

Boat survey methods

We conducted boat-based line transect surveys (Buckland et al. 2001) at a speed of ≤ 10 km/h aboard the National Park Service R/V Fog Lark, an 8.5 m landing craft with a large front deck that provided a viewing height of approximately 3 m above the water line for two observers. For all groups (murrelets of one species class in a flock) initially located on the water, observers recorded group size, species class (KIMU, MAMU, or unidentified), and estimates of distance and angle in a straight line projecting forward from the bow of the boat. The allowable Beaufort sea state was ≤ 2 . Program NPTransect (designed by R. Sarwas and W. Johnson, National Park Service) was used to record observations and associated GPS-based date/time/location stamps. As part of multi-observer method trials, on some transects a photographer located immediately behind survey observers collected images of a sample of murrelet groups detected by observers.

See the long-term monitoring protocol (Chapter 3 of the narrative, Standard Operating Procedures, hereafter “SOPs,” 1, 2, 3, and 9, and Appendix F) for more detail (Hoekman et al. 2013a).

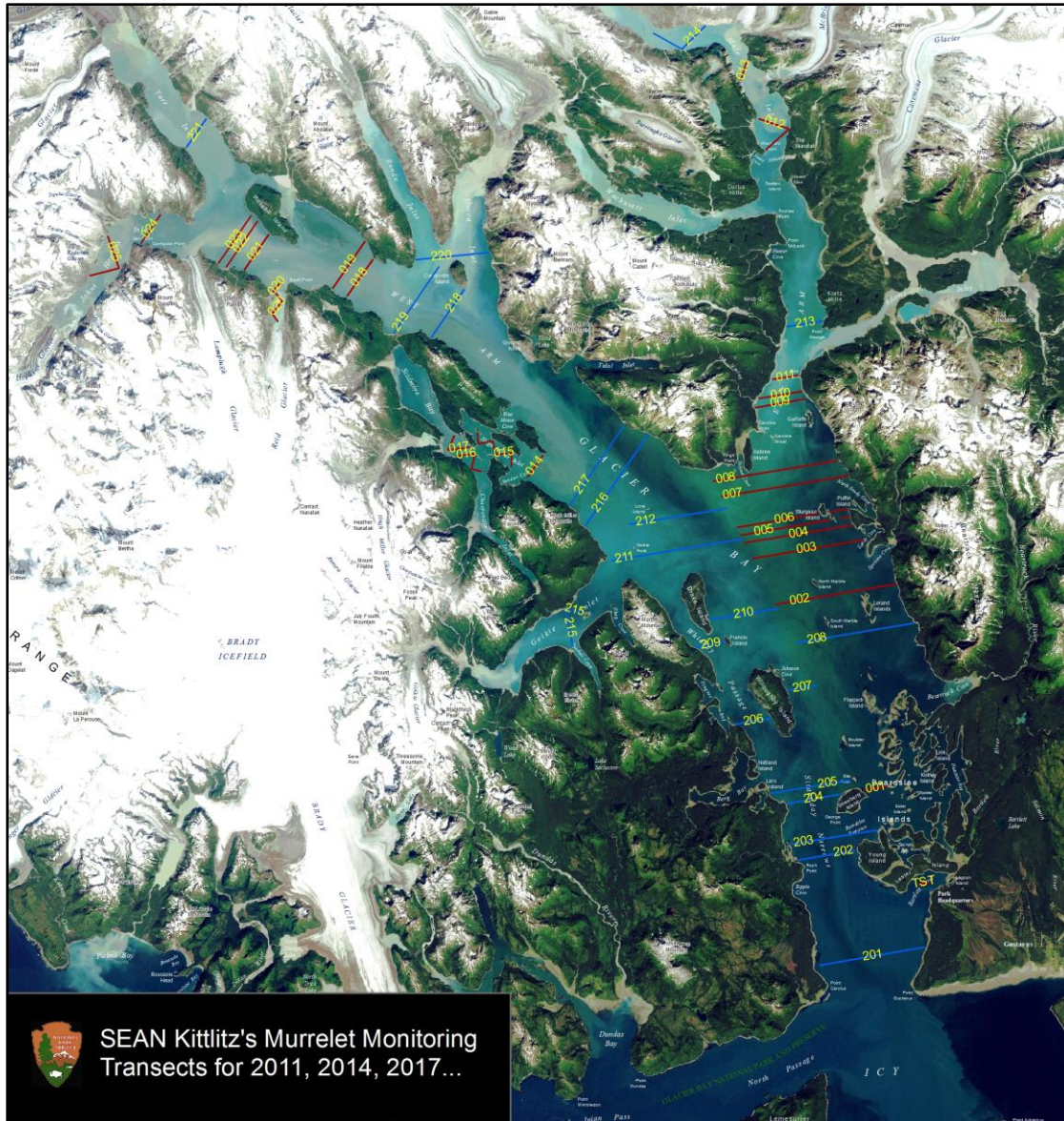


Figure 1. Line transects surveyed for murrelets in July 2014. Permanent (red lines) and Panel 2 (blue) transects were surveyed as part of an augmented, serially alternating panel design with a three-year rotation. Linear transects were used in open waters (>2.5 km wide) and zigzag transects were used in more restricted waters. Transects extended from shore to shore, except a few truncated at mid-Bay to maintain optimal transect length. Linear transects were oriented perpendicular to the prevailing shoreline. The orientation of zigzag transects relative to shore was determined by the width of each area.

Abundance estimation

We estimated detection probability and group size using Program DISTANCE version 6.0 (Thomas et al. 2010) and species-specific abundance using statistical software R version 2.13.0 (R Core Team 2013) following recommended distance sampling methods (Buckland et al. 2001) and protocol SOP 12 (Hoekman et al. 2013a). We modified distance sampling methods to account for incomplete detection near the transect center line and unidentified murrelets. Adjustments for unidentified murrelets assumed correct species identification and identical proportions of each species in the identified and unidentified samples. Density estimates were based on several component parameters: detection

probability across the transect width, detection probability near the center line, group size for each species class, and encounter rates for each species class. We estimated abundance by multiplying total study area (1,170 km²) by estimated densities.

See Hoekman et al. 2011c and the monitoring protocol (Appendices A and D, SOPs 11 and 12) for more detail.

Results

We surveyed 45 transects totaling 246.5 km from 7-16 July 2014 and detected 1,229 on-water groups. Due to heavy surface ice in Johns Hopkins Inlet, we were not able to survey transect 025 (5.63 km length). We classified 237 (19%) groups as KIMU, 724 (59%) as MAMU, and 268 (22%) as unidentified. Detection probability within 180 m of the transect center line was the lowest among all survey years (59%; Table 1). Thirty-nine percent of all observations were made during Beaufort sea state 0, 59% at 1, 2% at 2, and 0% greater than 2. Most observations (58%) were recorded during rain, mist, or fog, while 35% were recorded during greater than 50% cloud cover, and 8% during less than 50% cloud cover.

Our estimated effective strip width was 107 m. Estimated detection probability began dropping monotonically away from the center line, and decayed rapidly at longer distances (Figure 2). Higher average group size and encounter rates for MAMU (Table 1) resulted in estimates of on-water density and abundance approximately four times higher than KIMU (Table 2). Precision of estimated abundance, measured as the coefficient of variation (CV; in this case, standard error divided by the abundance estimate) was lower for KIMU (CV = 0.15) than MAMU (CV = 0.10). Density estimates since 2009 for each species show substantial annual variation in estimates and their precision (Figure 3). Estimated KIMU abundance was near the six-year average of abundance estimates and increased 45% from 2013. Estimated MAMU abundance was the second lowest on record and decreased 51% from 2013.

KIMU tended to concentrate higher in the bay in comparison to MAMU (Figure 4). The highest KIMU densities were encountered in the upper East Arm between Wachusett Inlet and McBride Glacier, and in the upper West Arm in Reid Inlet and the west side of Russell Island. KIMU were more sparsely distributed mid-bay and in the main channel of the West Arm. MAMU were densely distributed throughout the mid- and lower Glacier Bay regions, especially within Sitakaday Narrows and in the vicinity of North and South Sandy Coves. MAMU densities were generally lowest in the main channel of the West Arm (Figure 5).

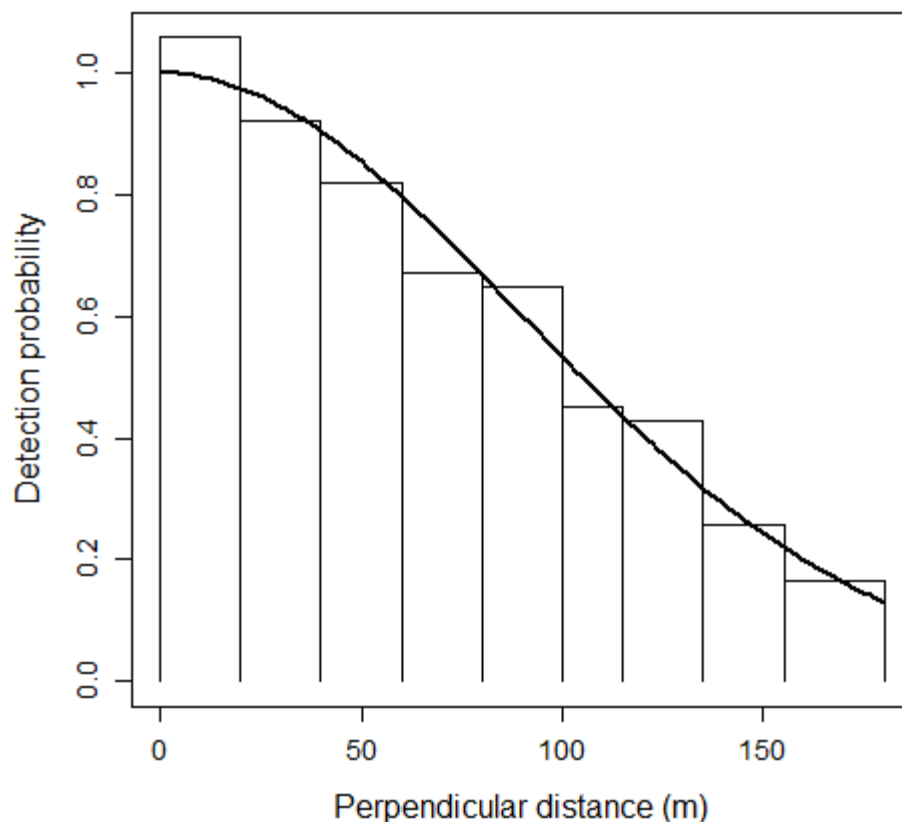


Figure 2. Estimated detection function for murrelets from line transect surveys in Glacier Bay, July 2014, illustrating estimated detection probability of murrelet groups relative to the perpendicular distances from the transect center line.

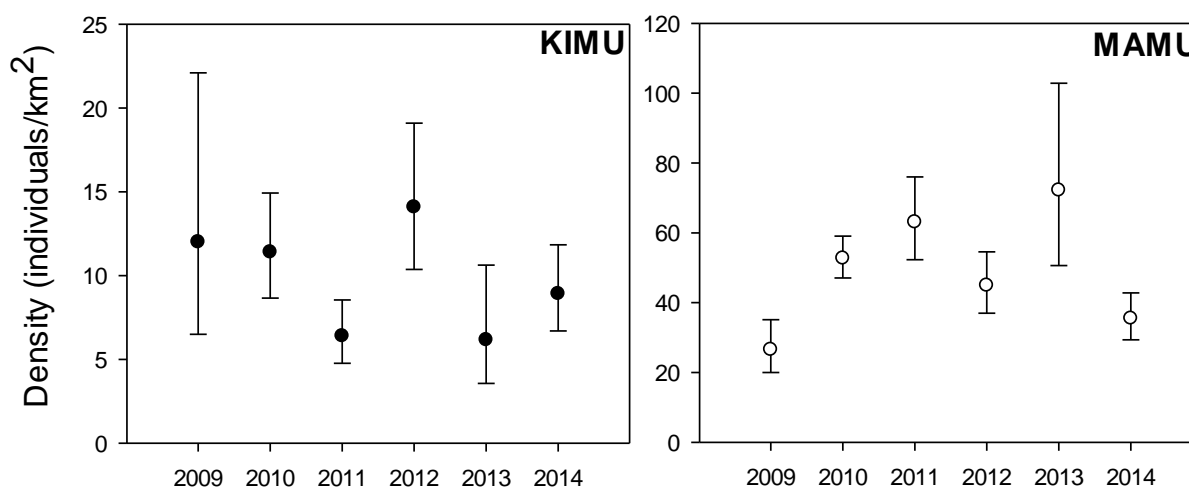


Figure 3. July densities (individuals/km²) of Kittlitz's (KIMU, black circles) and marbled murrelets (MAMU, white circles) in Glacier Bay survey area from 2009-2014. Error bars are 95% confidence intervals. Note separate y-axes for density and that 2009 estimates were based on pilot survey methods (Hoekman 2011a). Densities are displayed to control for differences in survey area for 2009 (1,092 km²) relative to 2010-2014 (1,170 km²).

Table 1. Component parameter values used to estimate on-water density and abundance of Kittlitz's and marbled murrelets in Glacier Bay for July 2014. Group sizes were estimated as single averages for each species class (see SOP 11 of protocol for more detail).

Parameter	Estimate	SE	P-value	Degrees of freedom
Detection across transect width	0.59	0.01		1179
Detection near transect center line ^a	0.94	0.03		66
Group size: Average				
Kittlitz's murrelet ^b	1.75	0.07		234
Marbled murrelet	2.16	0.06		702
Unidentified murrelet	2.43	0.18		241
Group size: Regression estimate				
Kittlitz's murrelet	1.76	0.07	0.74	234
Marbled murrelet ^b	2.02	0.04	0.018	701
Unidentified murrelet ^b	1.88	0.08	0.0036	240
Encounter rate (groups/km)				
Kittlitz's murrelet	0.81	0.11		43
Marbled murrelet	2.81	0.27		43
Unidentified murrelet	0.94	0.10		43

^a Estimate from Hoekman et al. 2011c.

^b Estimate selected for estimation of density and abundance.

Table 2. Estimates of on-water population density and abundance of Kittlitz's and marbled murrelets in Glacier Bay during July. Abundance was projected across surveyed waters only. Note that pilot surveys in 2009 differed in survey area (1,092 km²) and methods (Hoekman et al. 2011a).

Year	Kittlitz's murrelet				Marbled murrelet			
	Density ^a	SE	Abundance	SE	Density ^a	SE	Abundance	SE
2014	8.9	1.3	10,422	1,522	35.4	3.4	41,474	3,998
2013	6.2	1.7	7,210	2,046	72.2	13.2	84,428	15,394
2012	14.1	2.2	16,469	2,581	44.9	4.5	52,560	5,216
2011	6.4	1.0	7,477	1,119	63.1	6.0	73,766	7,055
2010	11.4	1.2	13,308	1,357	52.7	4.6	61,717	5,372
2009	12.0	3.7	13,124 ^b	4,062	26.5	3.7	28,978 ^b	4,077

^a Individuals/km²

^b Abundance extrapolated over 1,092 km² of sampled waters; all others extrapolated over 1,170 km².

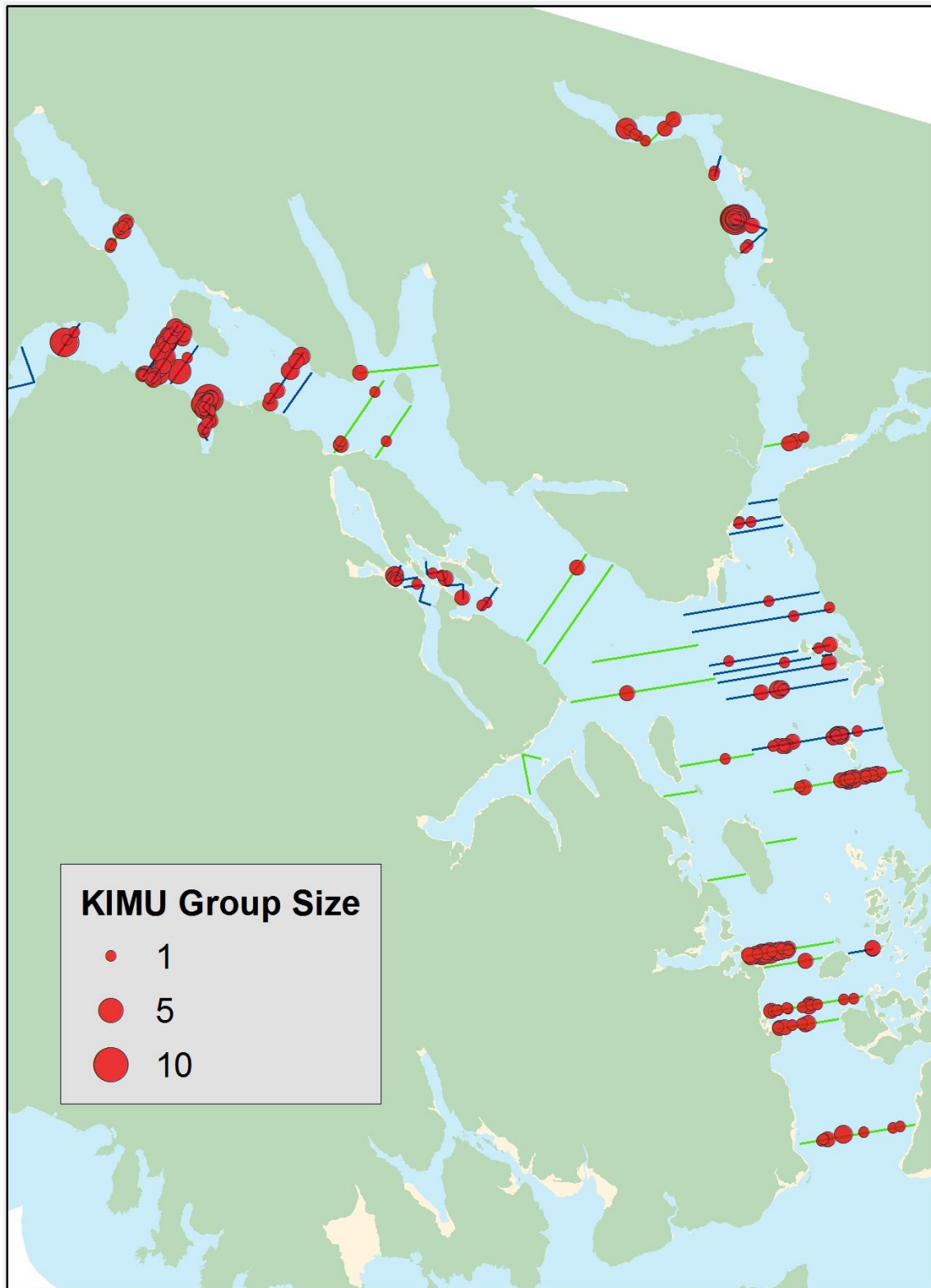


Figure 4. Spatial distribution of Kittlitz's murrelets observed during line transect surveys in Glacier Bay, July 2014. Lines indicate permanent transects (blue) and the current year's alternate panel transects (green). The area of circles is proportional to group size.

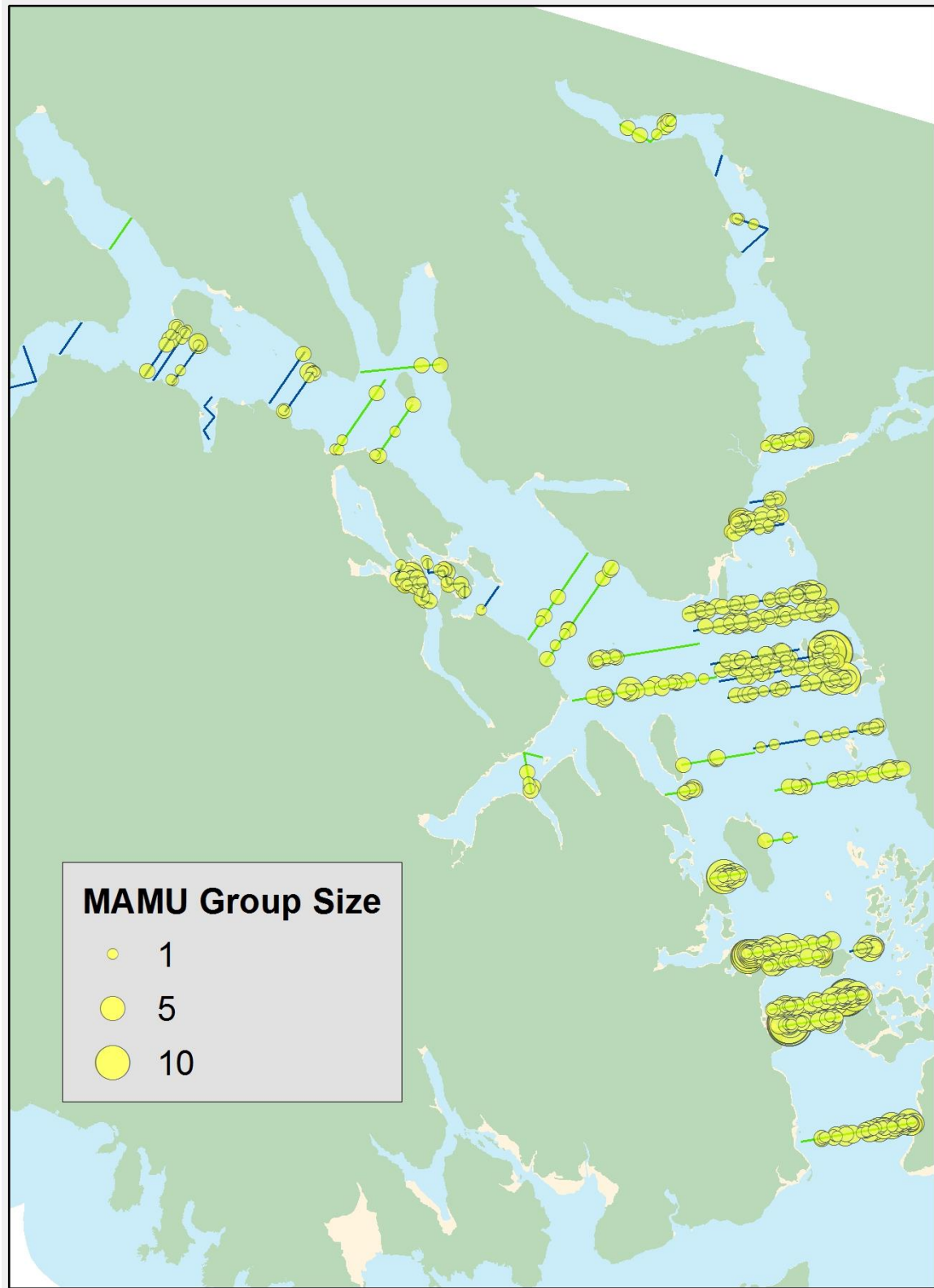


Figure 5. Spatial distribution of marbled murrelets observed during line transect surveys in Glacier Bay, July 2014. Lines indicate permanent transects (blue) and the current year's alternate panel transects (green). The area of circles is proportional to group size.

Discussion

Abundance estimates

The July 2014 on-water abundance estimate for KIMU in Glacier Bay was higher than 2013 and slightly less than the 6-year average abundance. From 2009 to 2014, our estimates of KIMU abundance in Glacier Bay have exceeded recent estimates from other breeding population centers in Alaska (Arimitsu et al. 2011; Day et al. 2011; Kissling et al. 2011; Kuletz et al. 2011a, b; Madison et al. 2011), and Glacier Bay's population continues to comprise an important fraction of the estimated minimum global population (USFWS 2013). Estimated 2014 MAMU abundance declined sharply from 2013 and was less than the 6-year average but, as seen every year since 2009, still greatly exceeded KIMU abundance. For both species, our 2009-2014 abundance estimates generally have greatly exceeded previous estimates for Glacier Bay (Drew et al. 2008, Kirchhoff 2008, Kirchhoff et al. 2010), although this may in part reflect differences in survey methods and timing. Kirchhoff and Lindell (2011), using line transect methods similar to ours, reported similarly high abundances for Glacier Bay during July 2010. As seen previously (Hoekman et al. 2011a, b, c), the relatively low precision of abundance estimates for KIMU resulted from higher among-transect variation in encounter rates arising from their more aggregated distribution. For both species in 2014, more evenly distributed populations, without large aggregations, resulted in relatively precise abundance estimates.

Abundance estimates for both species have been highly variable across 2009-2014. Estimates for KIMU have ranged from 7,210 to 16,469, with annual change ranging from -56% to 120%. MAMU estimates ranged from 28,978 to 84,428, with annual change ranging from -51% to 113%. Changes in estimates between years often appeared larger than could plausibly be attributed solely to intrinsic population growth (Table 2) given the life history of these species (Day et al. 1999, USFWS 2013). The effects of other potential factors contributing to changes in abundance estimates, such as change in proportion of the local breeding population on surveyed waters during sampling, immigration and emigration from and to other populations, or sampling error, remain unknown.

Detection and identification

Our overall estimated detection probability (59%) and effective strip width (107 m) were lower in 2014 than 2010-2013 (approximately 70-72% and 135-160 m, respectively). We attributed decreased detection to inclement weather, with far more observations recorded in rain and fog (58%) relative to prior years (0-14%). Despite impaired visibility, classification of murrelet groups to species (78%) slightly exceeded the long-term average. Factors we hypothesized to contribute to sufficient species identification include reduced sighting distances, improved observer training and skill, relatively low murrelet density and lack of large groups, and relatively low Beaufort sea states during observations. We note that the lowest species identification rates in 2012 (62%) were associated with the highest Beaufort states among 2009-2014 survey years (Hoekman et al. 2013c), suggesting an unstable viewing platform impedes species identification more than poor visibility caused by rain or fog. A robust detection function (Figure 2) satisfied criteria for estimating detection probability. Our methods of accounting for unidentified murrelets assume similar detection and identification rates for each species and, critically, minimal misidentification.

Most abundance estimation methods assume no species misidentification (e.g., Buckland et al. 2001), but failing to account for identification error when it occurs biases estimates of abundance and trend (Conn et al. 2013). During the July 2013 season, SEAN staff and volunteers participated in a GLBA field experiment conducted by A. Schaefer (University of Montana) that evaluated the magnitude of KIMU

versus MAMU identification error among six observers of differing experience levels and under a suite of environmental conditions.

Results indicated that identification error was low in this system, with an average of 0.036 (SE = 0.004) across all observers. Abundance estimates from Icy Bay, Alaska that were adjusted for uncertainty in species identification reflected little bias (Schaefer 2014). Observer experience was the main driver of variation in identification error rates, with more experienced observers making fewer errors. Therefore, these results emphasize the importance of conducting consistent, rigorous observer training before and during abundance surveys to increase confidence in species identification and precision in abundance estimates of both KIMU and MAMU.

KIMU spatial distribution

KIMU spatial distributions have shown considerable annual variation during our 2009-2014 (Hoekman et al. 2011a, b; 2013b, c; 2014) and prior 1999-2003 surveys (see Figure 8 in Drew et al. 2008). KIMU occurred throughout Glacier Bay but often aggregated in hotspots that differed in location and intensity among years. For 2009-2014 surveys, characterizing KIMU distributions relative to particular upper or lower regions of Glacier Bay has been difficult, but some patterns persist. Previous evidence closely linked KIMU to tidewater glaciers and glacial outwash (Kuletz et al. 2003). While KIMU typically have been more numerous in the upper East and West arms than the main bay, we have not consistently documented high occurrence of KIMU in fjord heads except for concentrations at the tidewater glacier in Reid Inlet. Instead, the most common July hotspots have been in the areas of middle West Arm, including Hugh Miller-Scidmore Complex and the west side of Russell Island, which are glacially-influenced waters but not adjacent to glaciers. In 2014, Hugh Miller-Scidmore Complex did not appear to be the usual hotspot observed in past surveys.

Our sampling design seeks to maximize precision of KIMU population estimates by allocating sampling intensity in proportion to expected densities of KIMU (see Hoekman et al. 2013a; Appendix B). Correspondence between expected densities and observed encounter rates has remained high for 2011 through 2014 surveys, and our allocation of effort has generally been successful in increasing sampling of areas with elevated KIMU densities. In 2014, KIMU occurred at moderate to low densities in sampling areas with low expected densities, but highest densities were limited to areas with high expected densities.

Recommendations

After the 2015 survey, a synthesis report will assess population abundance and trend, performance of analytic methods, and ability of the monitoring program to achieve its objectives. Although monitoring success depends in part on variability in murrelet populations within the survey area, our results and experience to date demonstrate that key operational components of our protocol are functioning as intended: equipment and personnel have been sufficient for timely completion of surveys; species identification rates have been adequate; procedures, hardware, and software for data collection have functioned well; detection probability has been high and detection functions have been robust; and our methods for allocating survey effort have generally been successful in increasing sampling where KIMU density is high. In the coming years, we expect the results of identification experiments conducted during 2013 and 2014 surveys (Schaefer 2014, S. Hoekman unpublished data) to inform potential modifications to monitoring methods, including incorporating identification uncertainty into adjusted abundance estimates.

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